Course Title: **Radiological Control Technician**
Module Title: **Sources of Radiation**
Module Number: **1.05**

Objectives:

1.05.01 Identify the following four sources of natural background radiation including the origin, radionuclides, variables, and contribution to exposure.
- a. Terrestrial
- b. Cosmic
- c. Internal Emitters
- d. Radon

1.05.02 Identify the following four sources of artificially produced radiation and the magnitude of dose received from each.
- a. Nuclear Fallout
- b. Medical Exposures
- c. Consumer Products
- d. Nuclear Facilities

References:

1. "Basic Radiation Protection Technology"; Gollnick, Daniel; Pacific Radiation Press; 1983.
2. ANL-88-26 (1988) "Operational Health Physics Training"; Moe, Harold; Argonne National Laboratory, Chicago.
3. NCRP Report No. 45 "Natural Background Radiation in the United States".
4. NCRP Report No. 56 "Radiation Exposure from Consumer Product Miscellaneous Sources".
5. NCRP Report No. 93 "Ionizing Radiation Exposure of the Population of the United States".

Instructional Aids:

1. Overheads
2. Overhead projector/screen
3. Chalkboard/whiteboard
4. Lessons Learned

I. MODULE INTRODUCTION

A. Self-Introduction

1. Name
2. Phone number
3. Background
4. Emergency procedure review

B. Motivation

1. Radiation sources are not limited to nuclear facilities. The study of sources provides data for:
   a. Basis for occupational exposures
   b. Effects from high source exposures
   c. Assesses impact from nuclear facilities
   d. Determines use of building materials

C. Overview of Lesson

1. Terrestrial radiation
2. Cosmic radiation
3. Internally emitted radiation
4. Radon
5. Nuclear fallout
6. Medical exposures
7. Consumer products
8. Nuclear facilities

D. Introduce Objectives

O.H.: Objectives

II. MODULE OUTLINE

A. Natural Background Radiation Sources

1. Terrestrial Radiation

a. Earth — Objective 1.05.01 a.

1) Source - small amounts of radioactive material found in rock and soil — Explain: Different books will use other dose rates. The references used here are NCRP reports.

2) Major isotopes: Uranium and Thorium

3) Exposure dependent on location

Atlantic and Gulf coastal = 15-35 mrem/yr
Greater U.S. = 35-75 mrem/yr
Colorado Plateau = 75-140 mrem/yr

4) Exposure dependent on type of soil

Volcanic - 125 mrem/yr
Sandstone - 50 mrem/yr
Limestone - 25 mrem/yr

5) U.S. average: 1 sq mile 1 ft deep contains 1 ton K-40, 3 tons U-238, 6 tons Th-232

6) Extremely high locations - due to high concentrations of monazite: — Monazite: a Thorium Mineral

Kerala India - Population is 70K

16K receive >500 mrem/yr
500 receive >2,000 mrem/yr
Highest: 5,865 mrem/yr

Minas Garais Brazil

Average: 1,160 mrem/yr
Max: 12,000 mrem/yr

b. Radioactivity in Water

1) All water contains some radioactivity

2) Examples

Sea water contains K-40
Natural springs contain U and Th
Rainwater picks up radioactivity from the air
Ground water picks up radioactivity from the soil
Contributor to internal doses

c. U.S. average of alpha emitters in water is <1 pCi/l

1) Colorado – 40-50 pCi/l

2) Brazil – 240 pCi/l (bottled water)

d. U.S. national average from terrestrial (NCRP Report No. 95) is 28 mrem/yr

2. Cosmic Radiation — Objective 1.05.01 b.

a. Natural radiation originating from outside of our atmosphere

b. Discovered during early terrestrial experiments with weather balloons

c. Primary

1) Galactic Cosmic Rays

From outside the solar system

Positively charged particles

- 87% protons
- 11% alpha
- 2% misc.

High energies - up to 10^{20} eV

2) Geomagnetically Trapped

When galactic rays approach earth, they must have enough energy to pass through magnetic fields

If they lack enough energy, they become trapped in two energy bands

- 1K - 3K meters
- 12K - 15K meters

3) Solar Cosmic Rays

Produced by severe solar flares

Consist mainly of protons

High energy - detected on ground

Low energy - detected at high alt.

Measurements

- 30,000 ft - 100 mr/hr
- 80,000 ft - 10 R/hr

Concern for high altitude space travel

d. Secondary

1) Results from the interaction of primaries with the earth's atmosphere

2) Cascade effect: one primary ionization = 100 million secondary ionizations

3) Products produced: pions, muons, electrons, photons, protons, neutrons

4) Primaries absorbed within the upper 10% of the atmosphere

5) Dominant components at ground level are penetrating muons and the electrons they produce.

6) Latitude contributes a small factor due to the earth's magnetic field

7) Exposures increase with altitude, decrease with latitude (Denver 50 mr/yr cosmic)

8) U.S. average = 27 mrem/yr

3. Internal Emitters (Food Chain)

Objective 1.05.01 c.

a. Results from the transfer of natural radiation from the food chain to man

b. Deposited internally from trace amounts found in soil, water and air

c. Isotopes: Primary - K-40
others - Rb-87, Ra-226, U-238, Po-210, C-14

d. U.S. national average is 39 mrem/yr from Internal Emitters

4. Radon

a. Due mostly to Radon and thoron gas

b. Radon is a product of the U-238 Series

U-238 $\rightarrow$Th-234 $\rightarrow$Pa-234 $\rightarrow$ U-234 $\rightarrow$ Th-230 $\rightarrow$ Ra-226 $\rightarrow$ Rn

c. Thoron is a product of the Th-232 series

Th-232 $\rightarrow$ Ra-228 $\rightarrow$Ac-228 $\rightarrow$Th-228 $\rightarrow$ Ra-224 $\rightarrow$ Rn-220

d. U and Th are present all over. Daughter products diffuse to the surface. These gases attach themselves to dusts and aerosols which are inhaled.

e. Radon concentrations are based on amounts of U and Th in the area

f. Factors:

- Weather (inversions)
- Indoor insulation
- Ventilation rate

g. High Areas:

- Colorado (Grand Junction) – mine tailings
- Pennsylvania – High radium concentration
- Underground mines, caves, caverns, etc.
- Helsinki – 240 rem to lung from radon

Most has been removed

h. U.S. national average for inhaled radionuclides is 200 mrem/yr.

B. Man Made Background Radiation Sources

1. Nuclear Fallout — Objective 1.05.02 a.

   a. Refers to the debris that settles as a result of weapons testing

   b. Contains over 200 fission products, bomb parts and all near-blast matter

   c. Dispersement is a function of:

      1) Bomb yield

         Kiloton Range - troposphere, 9,000 - 17,000 meters - easily washed down

         Megaton Range - Stratosphere, may stay aloft for five years

      2) Types of blast

         Surface burst
         Above ground

      3) Meteorological Factors - (weather)

   d. Weapons test ban treaty of 1962-63 limited testing

   e. U.S. average from nuclear fallout is <1 mrem/yr (NCRP #93)

2. Medical Exposures — Objective 1.05.02 b.

   a. Diagnostic X-rays

      1) Over 300,000 X-ray units in the U.S., about 67% of adult population is exposed each year

      2) X-ray machines consist of:

         a) X-ray tube

         b) HV Supply

         c) Filament

         d) Shielding

      3) Three general types:

a) Radiography - X-ray tube and a photographic plate (Chest, Dental)

b) Fluoroscope - Uses an image intensifier, observes internal processes

c) Photofluorographic - Fluorescent screen and camera, large amounts of people

4) U.S. national average from diagnostic X-rays is 39 mrem/yr

b. Medical Radionuclides (Two Types)

1) Nuclear Medicine

Used to diagnose medical problems

Attaches a radionuclide to a pharmaceutical that will seek a particular organ

- Radionuclide selection:
- Photon emitter
- Short lived

Tc-99m, In-113m

2) Radiation Oncology

Uses high energy power source to treat tumors

Typical 6,000 Curie Co-60 source delivers 100 Rad/min

3) NCRP report 93 gives the dose equivalent for medical radionuclides as 14 mrem/yr

c. Both contributors to Medical Exposures combine for 53 mrem/yr major types of medical exposures

3. Consumer Products (NCRP Report 56)

Objective 1.05.02 c.

a. Television (Example)

1) Source -- X-rays from High Voltage a few.

2) Limit (1960) -- 0.5 mr/hr at 5 cm

3) 1967 - 149 big screen TVs were recalled, 2 emitted greater than 100 mRad/hr

4) U.S. average -- 0.5 to 1.5 mr/yr

b. Shoe fitting fluoroscopes (Example)

1) Source - X-ray tube

2) 1953 - 10,000 in use

3) Exposures - 7 to 14 R per 20 sec exposure GSD - 30 to 170 mr

c. Radioluminous Watches (Example)

1) Source - Ra-226 "Glow in the Dark"

2) 10,000,000 still in use

3) Pr-147 and H-3 used today

d. Dental Prosthesis (Example)

1) Dentures used to be doped with U resulting in up to 600 rem/yr to the oral mucosa

e. Hundreds of other products contribute

1) U.S. national average from all consumer products is 10 mrem/yr

4. Nuclear Facilities

Objective 1.05.02 d.

a. Public exposures from

1) Mining (several hundred) and milling (20 mills)

2) Fuel Fabrication (21 facilities)

3) Reactors (~90 power, 300 non-power)

b. U.S. national average - <1 mrem/yr

III. SUMMARY

A. Review major topics

1. Terrestrial radiation

2. Cosmic radiation

3. Internally emitted

4. Radon
5. Nuclear fallout
6. Medical exposures
7. Consumer products
8. Nuclear facilities

B. Review learning objectives

IV. EVALUATION

Evaluation should consist of a written examination comprised of multiple choice questions. 80% should be the minimum passing criteria for the examination.